

CS 2210 – Logic for Computer Scientists

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Semantic Web as an Application Area for Logic

1. **What is Semantic Web?**
2. Query Answering on the Web
3. Semantic Search
4. Semantic Web Services

The WWW is penetrating our society



- **Social contacts (social networking platforms, blogging, ...)**
- **Economics (buying, selling, advertising, ...)**
- **Administration (eGovernment)**
- **Education (eLearning, Web as information system, ...)**
- **Work life (information gathering and sharing)**
- **Recreation (games, role play, creativity, ...)**

- Immensely successful.
- Huge amounts of data.
- Syntax standards for transfer of structured data.
- Machine-processable, human-readable documents.



BUT:

- Content/knowledge cannot be accessed by machines.
Meaning (semantics) of transferred data is not accessible.

- **Too much information with too little structure and made for human consumption**
 - Content search is very simplistic
 - future requires better methods
- **Web content is heterogeneous**
 - in terms of content
 - in terms of structure
 - in terms of character encoding
 - future requires intelligent information integration
- **Humans can derive new (implicit) information from given pieces of information**
but on the current Web we can only deal with syntax
 - requires automated reasoning techniques

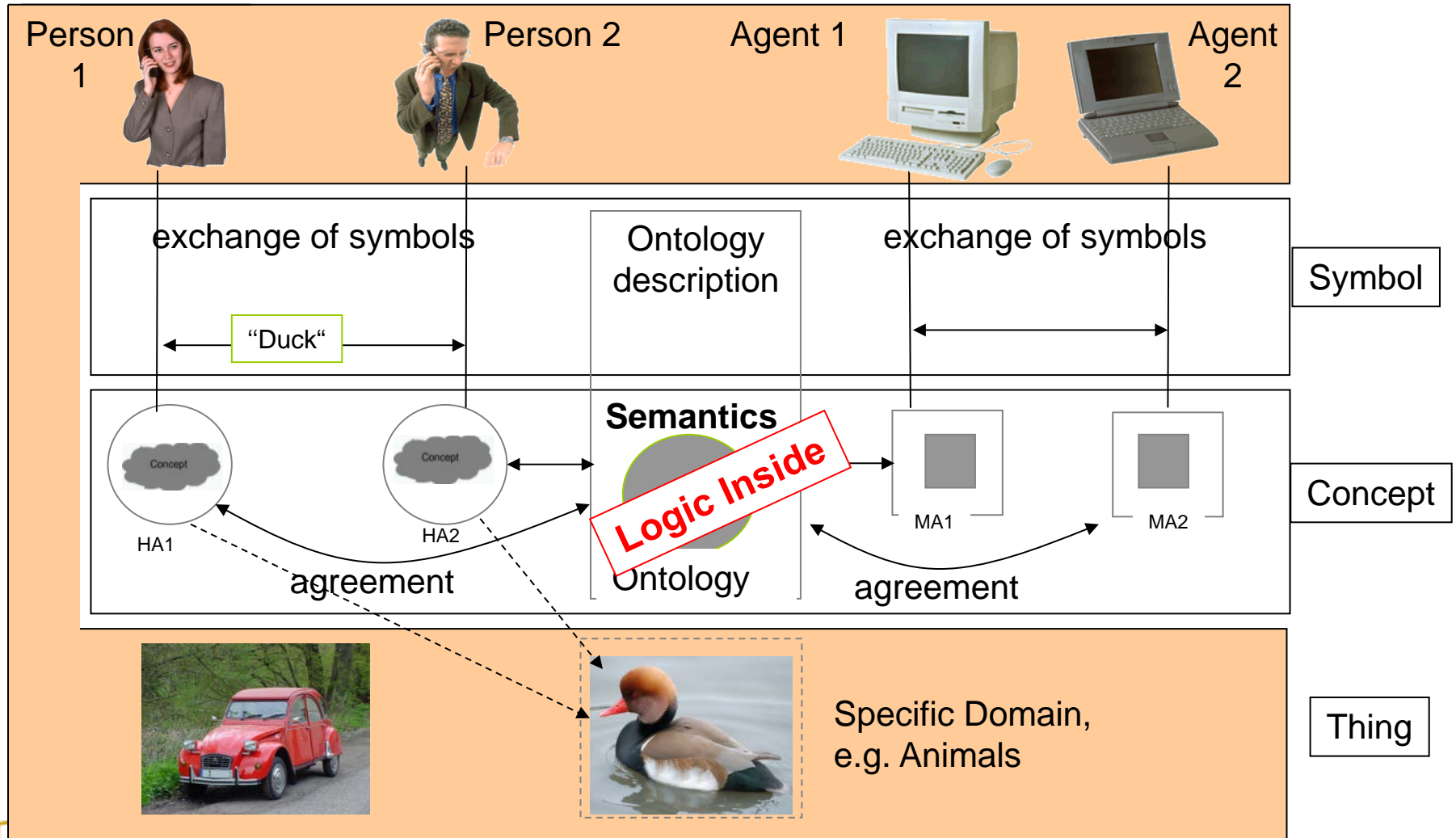
- **What tribe has lived since 1300 AD near the canyon you'd explore from Bright Angel Trail?**
- **The highway that runs through Rachel, Nevada draws enthusiasts who probably enjoy what movie genre?**
- **If you key in international dialing code 40, how would you say "good morning" in the language of the country you're calling?**
- **What word will you use for "taxi" if the airport code of your destination is OSL?**
- **What single state is home to all of the following U.S. cities: Madrid, Toronto, Cincinnati, Denver, Hartford, and Norway?**

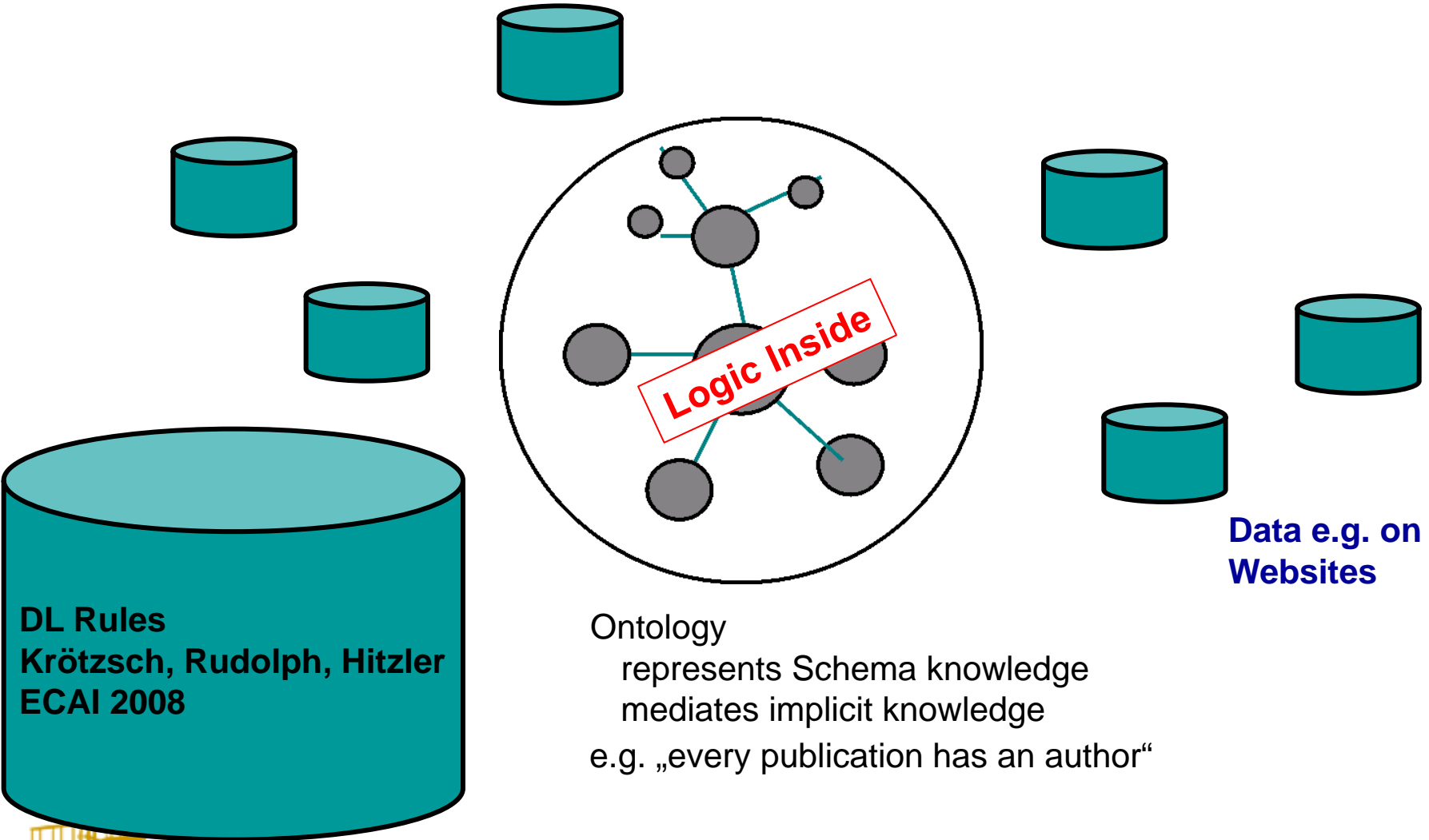
“Identify congress members, who have voted “No” on pro environmental legislation in the past four years, with high-pollution industry in their congressional districts.”

In principle, all the required knowledge is on the Web – most of it even in machine-readable form.

However, without automated processing and reasoning we cannot obtain a useful answer.

- **Open Standards for describing information on the Web**
- **Methods for obtaining further information from such descriptions**
 - ! e.g. by automated logical reasoning

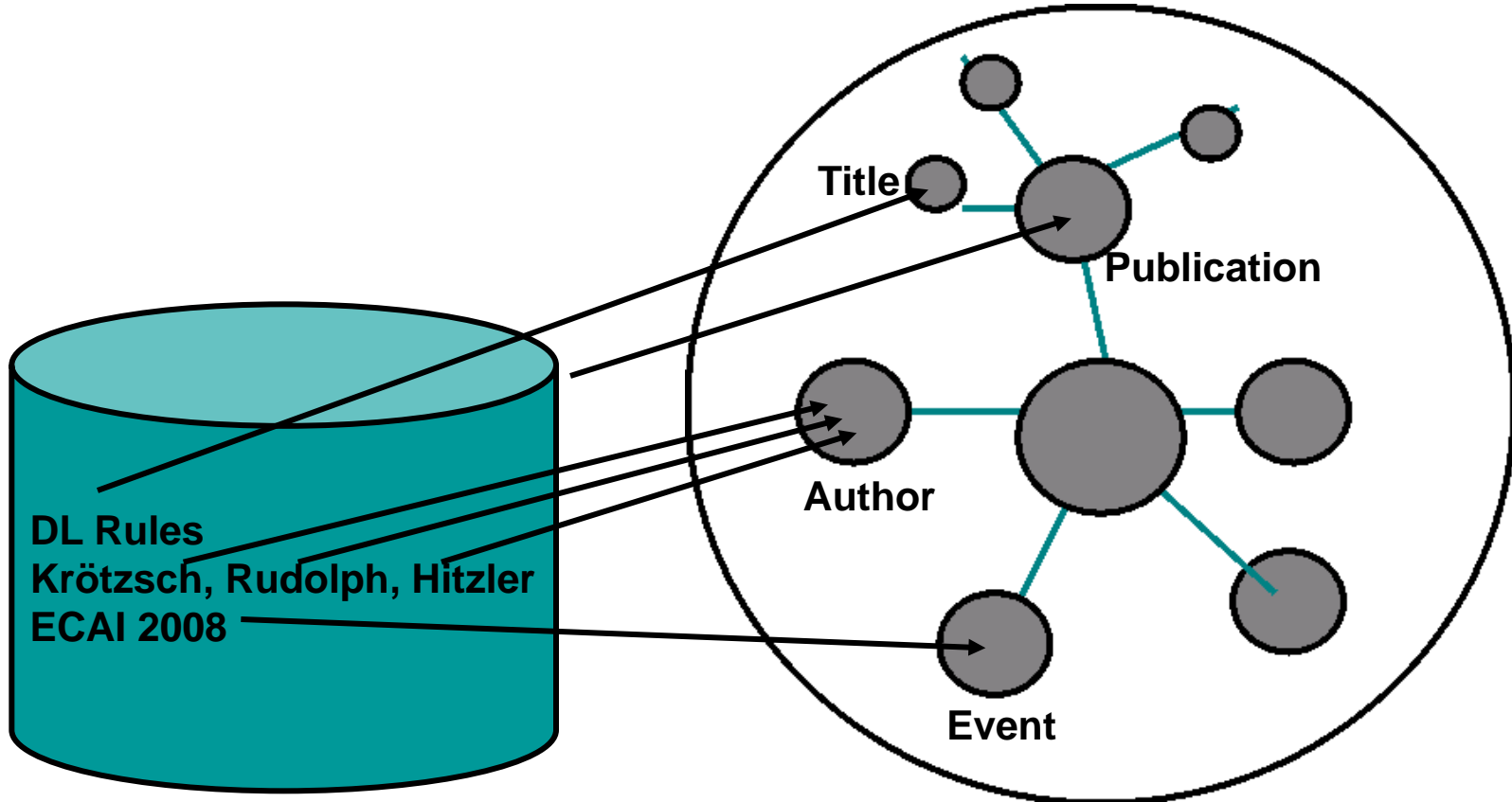




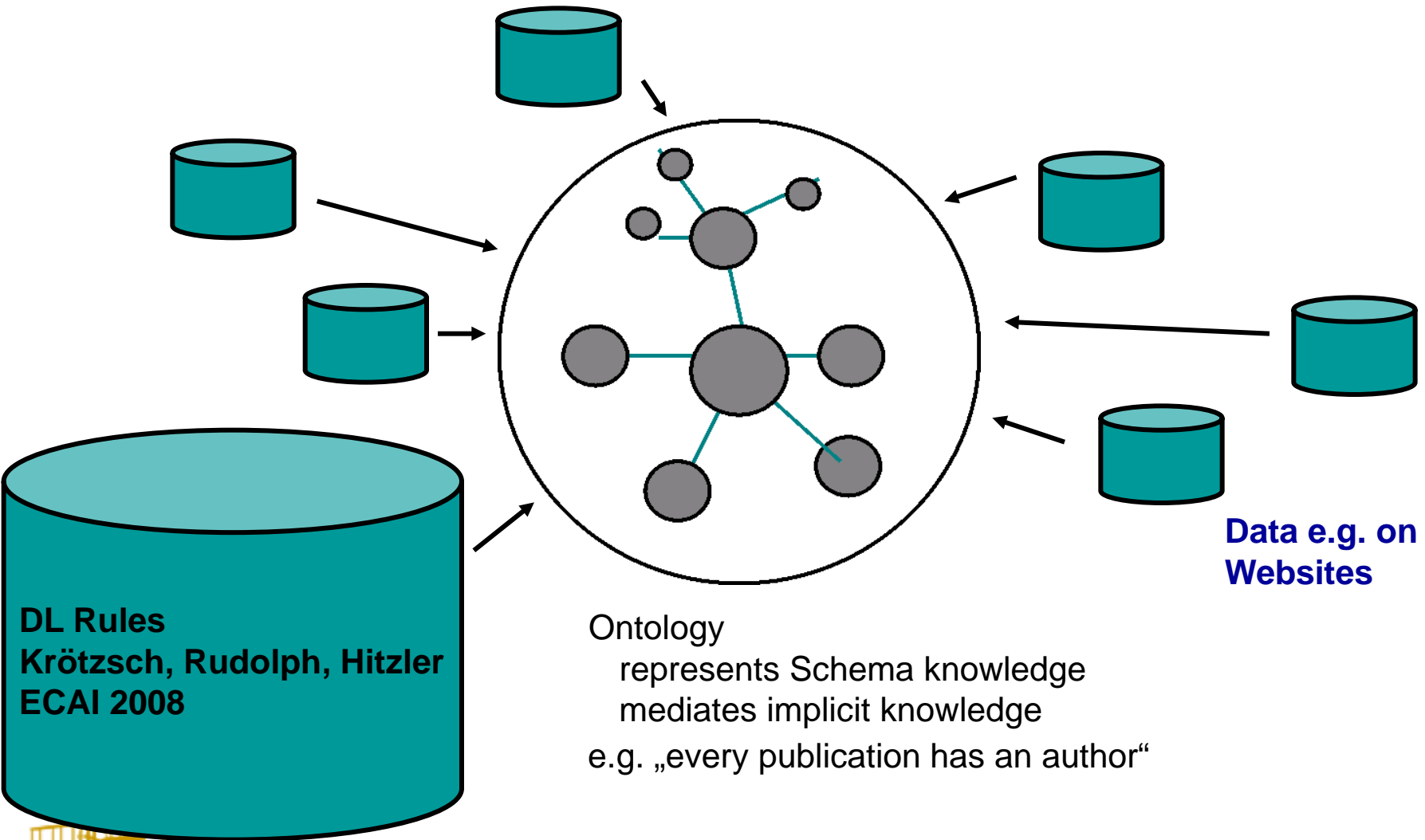
DL Rules
Krötzsch, Rudolph, Hitzler
ECAI 2008

Ontology
represents Schema knowledge
mediates implicit knowledge
e.g. „every publication has an author“

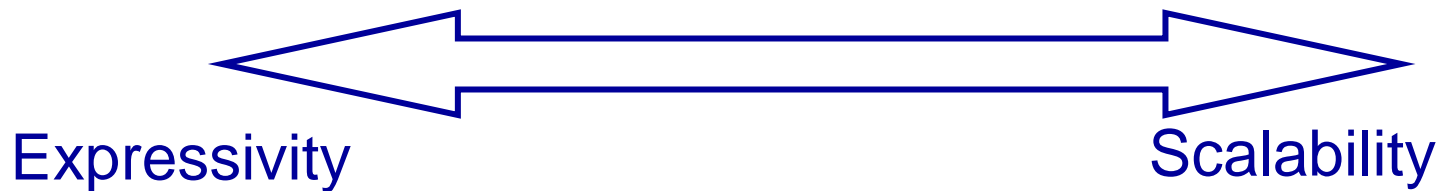
Data e.g. on
Websites



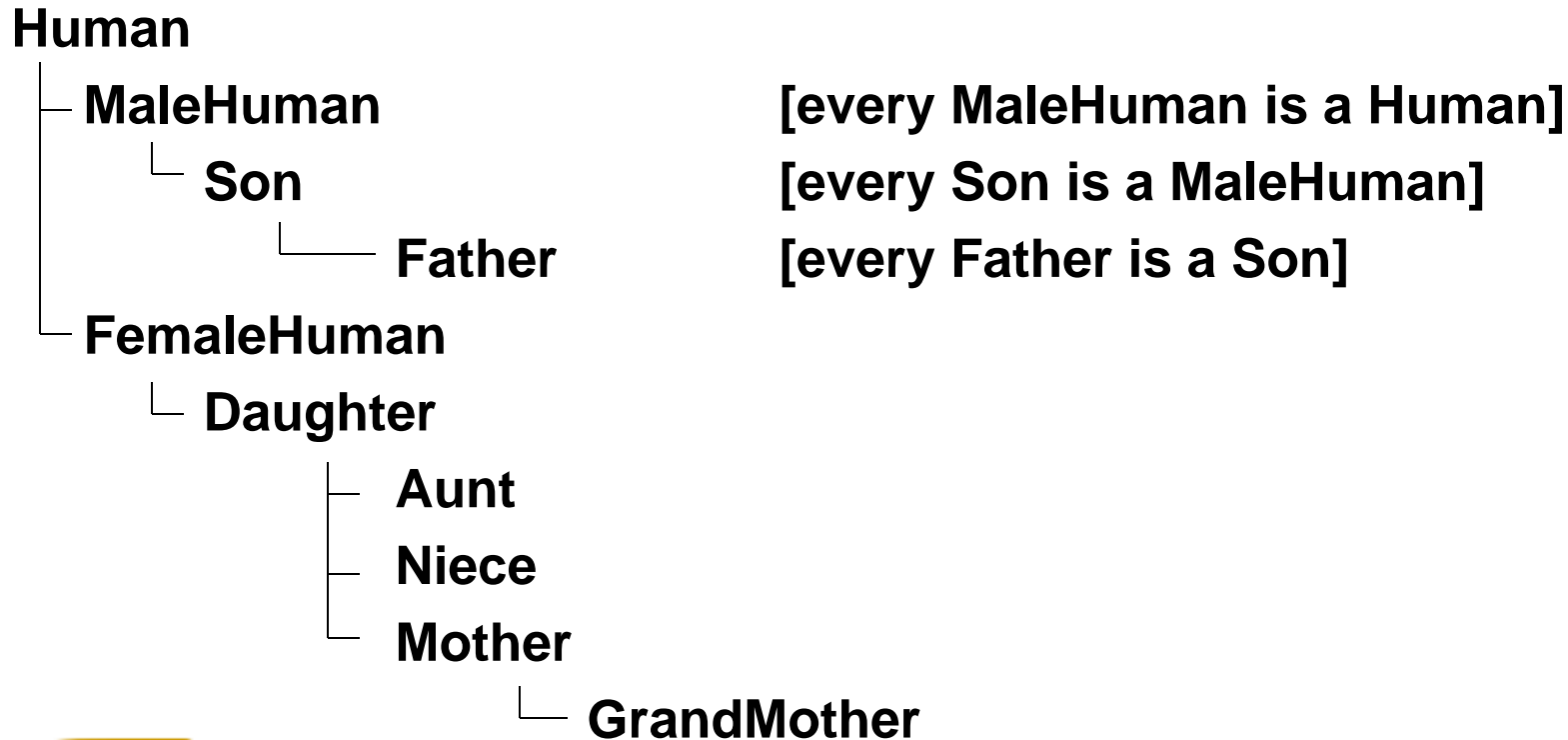
e.g. „every publication has an author“



- Of central importance for the realisation of Semantic Technologies are suitable representation languages.
- Meaning (semantics) provided via logic and deduction algorithms (automated reasoning).
- Scalability is a challenge.

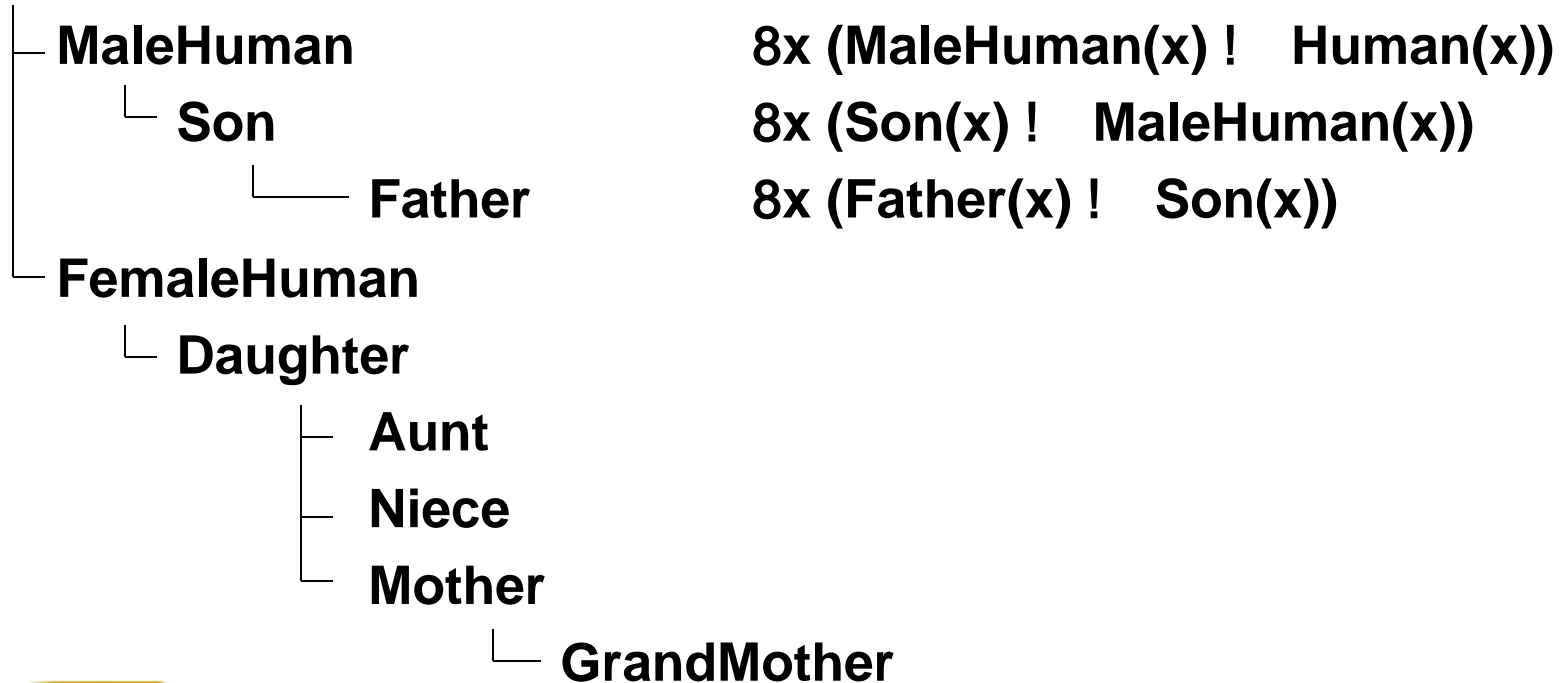


- The core of an ontology is often a *taxonomy*:
 - classes of things, arranged in a hierarchy



- Logically speaking ...

Human



But you can do much more, e.g.

- ***Web Ontology Language* OWL**
W3C Recommendation 2004 (OWL 2: 2009)
- **OWL is essentially a sublanguage of First-order Predicate Logic**
- **For OWL reasoning, (a suitable variant of the) tableaux algorithm is commonly used.**

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Just learned [79°26'01.86"W is the longitude of Dufferin Mall](#)

What would you like to know?

? answer

e.g. [Is Chris Evert male or female?](#) [What is another word for fantastic?](#) [more...](#)

Answering questions based on 274,033,896 facts on 8,992,129 things

Live questions: [rebeca linares birthday](#) ? [population of california 2010](#) ? [convert 250 kmh to mph](#) ? [population of paraguay in 2010](#) ? [more](#)

The world's first AI question-answering platform.

We are using our unique semantic technology to build the first internet-scale platform for directly answering the world's questions. As knowledge is added to the platform we understand and answer more and more.

Teach True Knowledge

You can contribute to True Knowledge by teaching it something new. You can add:

 A person  A business  Anything else

Or teach us a fact:

e.g. [I have always been unmarried](#)

Teach

[recent activity](#) [league table](#) [community](#)

We're hiring!

We are looking for passionate and talented individuals to join our growing team. Visit our [jobs pages](#) to see if True Knowledge is right for you.

Enhanced Search

Traditional search engines don't understand what your question actually means — they simply scan web pages for matching words. Use our search enhancer to add intelligence to your search results.



Install search enhancer

What would you like to know?

? answer

Are Lobsters spiders?

Share this:   

Rate this answer:  vote up  vote down  report abuse

No



Lobster

Clawed lobstershola, comprising a family of large marine crustaceans

[wikipedia](#)



spider

spider (the 8-legged invertebrate)

[wikipedia](#)

▼ How do we know?

Analyse this question

✓ See facts...

Reasoning 

I followed this chain of reasoning...

I know from locally stored knowledge that:

[Lobster](#) is a subclass of [Crustacean](#) ((fact: ["130986959@trueknowledge.com"]))

Therefore (generator: ["dc2@trueknowledge.com"]):

[Lobster](#) is a distinct class from [spider](#)

Therefore (generator: ["subclassdistinct1@trueknowledge.com"]):

[Lobster](#) is not a subclass of [spider](#)

Is Garfield a cat?


What would you like to know?

Is garfield a cat?

? answer

Is garfield a cat?

Share this:   

Rate this answer:  vote up  vote down  report abuse

No



[domestic cat](#)

cat, also known as the domestic cat or house cat to distinguish it from other felines, a small carnivorous species of nocturnal mammal that is often valued by humans for its companionship and its ability to hunt vermin

[wikipedia](#)



[James Garfield](#)

James A Garfield, the 20th President of the USA


[wikipedia](#)

Garfield is not a cat

▼ How do we know this?

Analyse this question

✓ See facts...

Reasoning 

I followed this chain of reasoning...

I know from locally stored knowledge that:

Fact 1: James Garfield is a President ([fact: ["378042683@trueknowledge.com"]])

Fact 1: is true for March 5th 1881 - September 19th 1881 ([fact: ["378042691@trueknowledge.com"]])

President is a subclass of person ([fact: ["123985229@trueknowledge.com"]])

Therefore (generator: ["dc2@trueknowledge.com"]):

President is a distinct class from domestic cat

Therefore (generator: ["distinct1@trueknowledge.com"]):

Fact 2 James Garfield is not a domestic cat

By calculation (generator: ["distinct1@trueknowledge.com"]) I know that:

Fact 2: is true for March 5th 1881 - September 19th 1881

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3. **Semantic Search**
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Find that landmark article on commonsense reasoning written by an Canadian researcher in 1980.

**The information is on the web.
We just cannot combine it easily.**

hasNationality(RaymondReiter,canadian)

[Wikipedia]

hasTopic(paper3546, nonMonotonicLogic)

[publisher]

hasAuthor(paper3546,RaymondReiter)

hasYear(paper3546,1980)

hasCitations(paper3546,2011)

[microsoft acad. search]

subTopicOf(nonMonotonicLogic,commonsenseReasoning)

[knowledge base]

$\exists x \exists y \exists z (\text{hasTopic}(x,y) \wedge \text{subTopicOf}(y,z) \wedge \text{hasTopic}(x,z))$

$\exists x \exists n (\text{hasCitations}(x,n) \wedge \exists x, n \text{ landmarkPaper}(x))$

[publication finder]

Then we can ask, for which $?x$ and $?y$ the formula

$\text{landmarkPaper}(?x) \wedge \text{hasYear}(?x,1980) \wedge$

$\text{hasTopic}(?x,\text{commonsenseReasoning}) \wedge \text{hasAuthor}(?x,?y) \wedge$

$\text{hasNationality}(?y,\text{canadian})$

is a logical consequence of the above.

Semantic Web as an Application Area for Logic

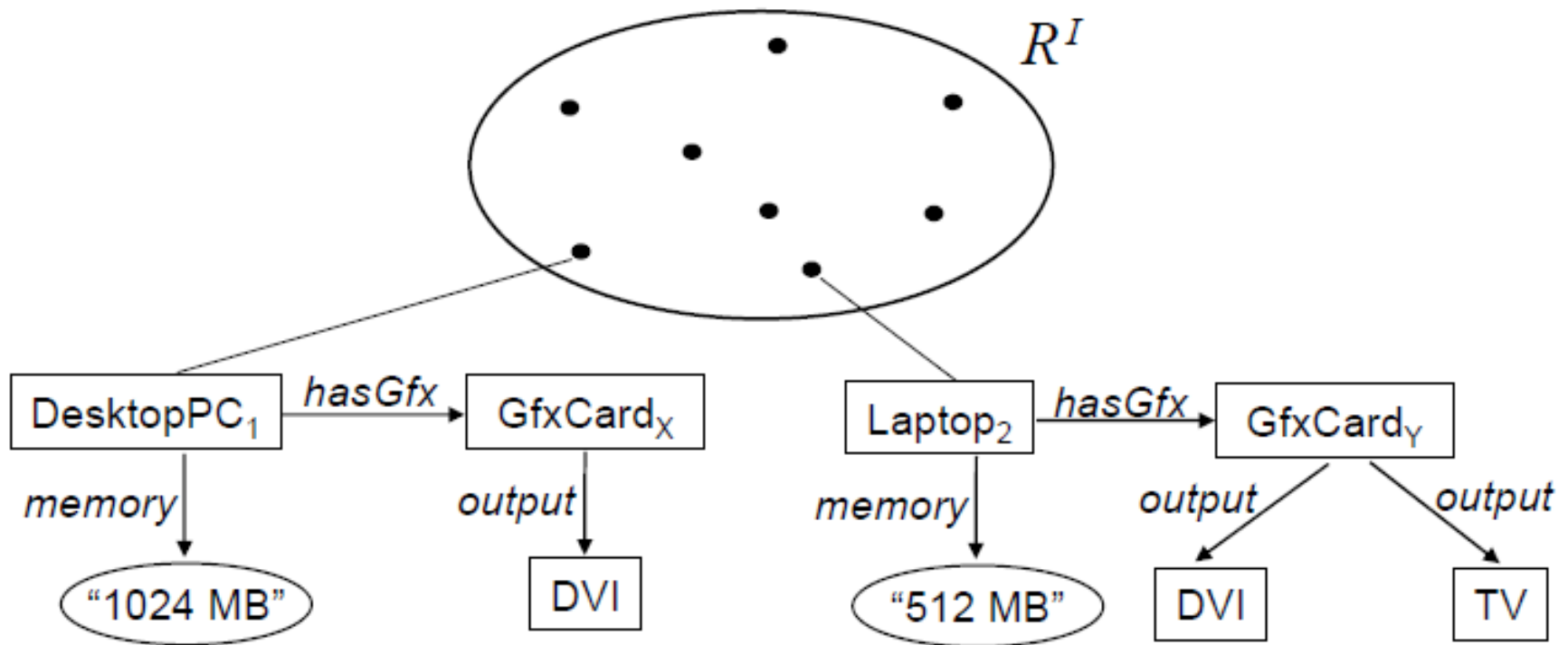
1. What is Semantic Web?
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4. **Semantic Web Services**

- Internet shops selling computers.
- You want to buy one which satisfies your specifications.
- Shop offers can be described using OWL.
- Your specifications can be described using OWL.
- Automated reasoning can be used to see if there is a match.

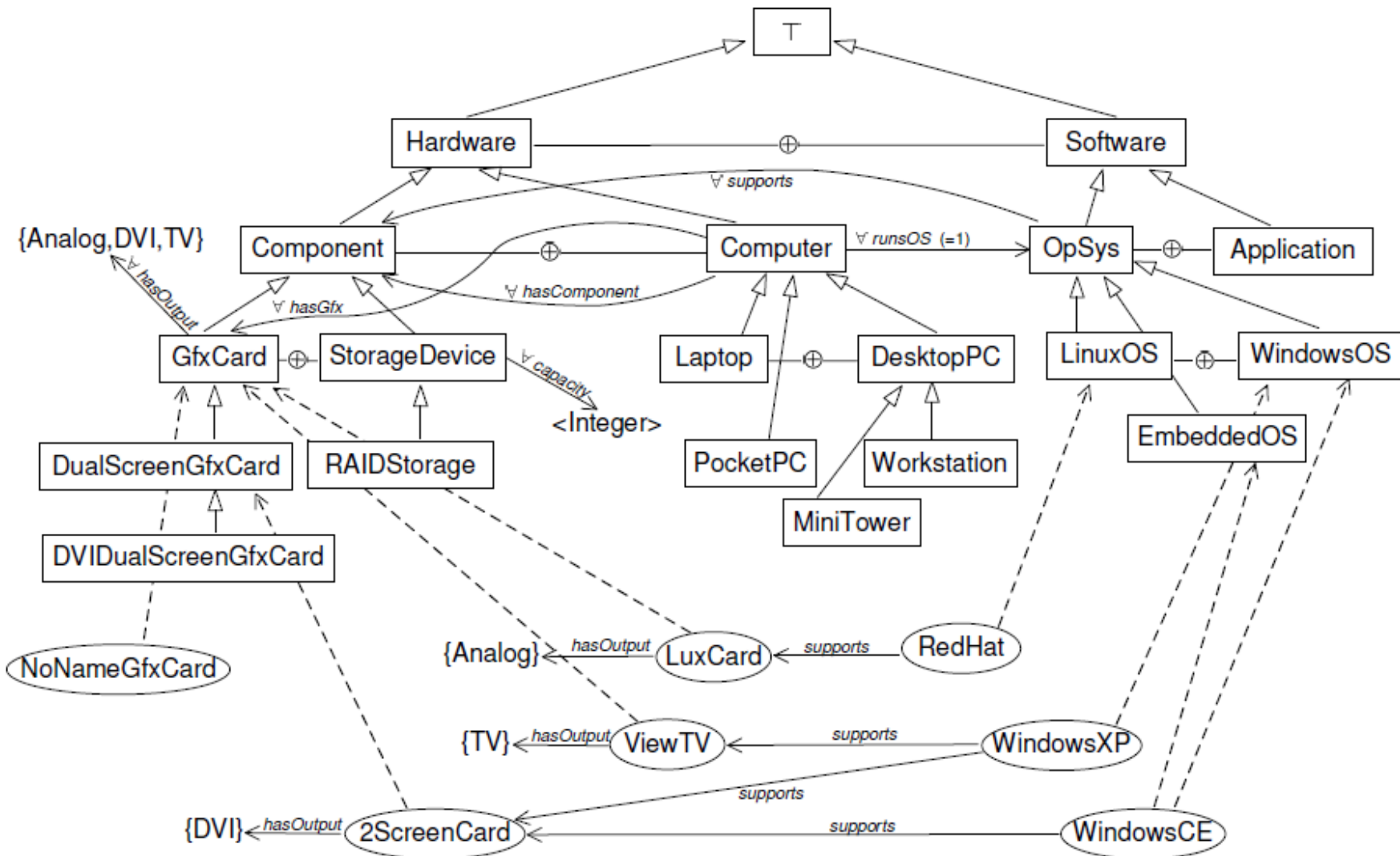
Resource description example

$$R = \text{Computer} \sqcap \exists \text{memory}.\geq_{512} \sqcap \forall \text{hasGfx}.\left(\exists \text{output}.\{DVI\}\right)$$

$\exists x (\text{Computer}(x) \wedge \exists n (\text{memory}(x,n) \wedge n \geq 512) \wedge \exists y (\text{hasGfx}(x,y) \wedge \exists \text{output}(y,DVI)))$



Background Knowledge (part)



$$S_A = \text{MiniTower} \sqcap \exists \text{hasGfx} . \text{DVIDualScreenGfxCard}$$
$$D_1 = \text{Computer} \sqcap \exists \text{hasGfx} . \text{DualScreenGfxCard} \\ \sqcap \forall \text{hasComponent} . (\exists \text{supports}^- . \text{WindowsOS})$$
$$\exists x (S_A(x) \ \$ \ (\text{MiniTower}(x) \ \wedge \exists y (\text{hasGfx}(x,y) \ \wedge \text{DVIDualScrGfxCard}(y))))$$
$$\exists x (D_1(x) \ \$ \ (\text{Computer}(x) \ \wedge \exists y (\text{hasGfx}(x,y) \ \wedge \text{DualScreenGfxCard}(y)) \ \wedge \\ \exists z (\text{hasComponent}(x,z) \ \wedge \exists w (\text{supports}(w,z) \ \wedge \text{WindowsOS}(z))))))$$

- Logical Consequence:

$$S_A \cup D_1 \neq ; \\ \exists x (S_A(x) \ \wedge D_1(x))$$

i.e., the supply meets the demand.

$S_A = \text{MiniTower} \sqcap \exists \text{hasGfx} . \text{DVIDualScreenGfxCard}$

$D_2 = \text{DesktopPC} \sqcap \exists \text{hasStorage} . \text{RAIDStorage}$

$\sqcap \exists \text{runsOS} . (\exists \text{supports} . \text{DualScreenGfxCard}$
 $\sqcap \exists \text{supports} . \text{RAIDStorage})$

- In this case,

$$\mathbf{S_A \sqcup D_2 = ;}$$
$$\mathbf{: 9x (S_A(x) \sqcap D_2(x))}$$

(Complete example: Reference [3])

- **Large and active research area**
- **Recently considerable industrial impact**

- **Wright State University is one of the leading US players in this area.**

- **Interested in pursuing reseach? Thesis? Independent Study?
) just let me know, and we can talk about options.**

- [1] Pascal Hitzler, Markus Krötzsch, Sebastian Rudolph
Foundations of Semantic Web Technologies.
Textbooks in Computing, Chapman and Hall/CRC Press, 2010.
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- [2] Pascal Hitzler, Markus Krötzsch, Bijan Parsia, Peter F. Patel-Schneider, Sebastian Rudolph
OWL 2 Web Ontology Language: Primer.
W3C Recommendation, 27 October 2009.
<http://www.w3.org/TR/owl2-primer/>
- [3] Stephan Grimm, Pascal Hitzler
Semantic Matchmaking of Web Resources with Local Closed-World Reasoning.
International Journal of e-Commerce 12 (2), 89-126, Winter 2007-8.